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# Analysis on the influence of fire overhangs on the window to exterior wall vertical fire plume spreading under external wind

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**Abstract**

The blocked performance of the fire canopy to vertical fire plume spread was studied by 1/2 scale building external facade flame experiment and FDS numerical simulation, and the blocked performance of the fire canopy to vertical fire plume spread was studied under external wind by FDS. The results showed that when the extending length of the fire canopy reached 0.6 m, it could block the vertical spread of openings overflow fire plume effectively; when the wind speed reached 3 m/s, the height of windowsill walls reached 0.4 m, the fire canopy could still block vertical fire plume spread.


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*Key words:* building exterior; wall openings overflow fire plum; fire canopy; external wind.

## 1. Introduction

With the development of modern society, the height of building and the number of tall buildings is increasing rapidly all over the country [1]. However, the fire broken out at building facade of tall building has taken place frequently recent years, and it caused serious casualties. Flame spread rapidly along the vertical building facade, and it is easy to make the flame spread along horizontal direction under the control of the influence of external wind and caused the building form a three-dimensional fire which will make a great threat to main structure of high-rise building and security of internal personnel [2]. Therefore, it is significant to take the research of the structure barrier effect of building facade's facilities under the external wind.

On the windless condition, the indoor combustion under the sense of risk control system, namely the indoor oxygen is not enough to sustain a lot of fuel combustion, so as to make part of unburned material overflow through the opening and burn outside. Under this condition, fire plume spreads vertically under the effect of thermal buoyancy. At the state of the wind, the vertical spreading of fire plume will deviate in horizontal under thermal buoyancy and horizontal wind force, and it will increase the speed of heat convection and cause the combustion of unburned material become more fully, and poses great threat to the floor above the burning floor [3,4,5]. Therefore, for building facade overflow spreading fire, it will cause great threat when fire plume spread to the upper window or horizontal window.

In order to avoid three-dimensional fire formed on building facade under the effect of external wind, it must depend on structure barrier facilities. Windowsill wall and fire canopy are two effective structure barrier facilities to stop the vertical spread of the fire plume [6]. Zhao et al [7]. studied the barrier effect of windowsill wall, balcony and pier to horizontal spread of overflowing fire plume on building façade in the case of high-speed and low-speed wind. Results show that under the low-speed wind, the extended width of the balcony plays a main function since pier plays the main role under the high-speed wind. But the research of the blocked effect of windowsill wall's and fire canopy barrier's to vertical spread overflow fire at different wind speed is less. Based on the research status at home and abroad, this page takes an in-depth research of

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the fire canopy's barrier effect to vertical spread overflow fire at different wind speed by 1/2 scale building external facade flame experiment and FDS numerical simulation.

## 2.1/2 scale building external facade flame experiment

### *2.1 Experiment table setup*

1/2 scale experiment table divide into 3 floor, according to the selected proportional relations and 1/2 scale, the geometry size is 4720 mm * 3780 mm * 4500 mm. The size of each room at each floor is 1.5 m * 3.3 m * 3.3 m (length x width x height), and the fire in the right room is 0.2 m away from the window of first floor. The adjustable fire overhangs are installed between the first and the second floor and the central between second and third floor. The fire overhangs are made of steel of which is 1.5 m in length and 0.1 m in width. The extended length of the fire overhangs is changed by installing and discharging the fire overhangs in this experiment. The Smooth frame added with fire overhangs is installed above the fire floor, and it can put 8 fire overhangs on it. Namely, it can extend to 0.8m since each fire overhang is 0.1m in width.

Figure 1: Experiment table

### *2.2 Fire power and the location of measure point*

In this experiment, we used methanol as fire source and the size of it is 0.8 m * 0.8 m * 0.8 m and arranged at 0.2m from window. In order to ensure the indentation size model can show the same fire behavior of full size model, both of the original variable need to follow the proportional relations listed on table 1.

In the room with water spray and office, according to the data shown in the table, the PHRR is 1.5MW since the object of this research are office buildings and residential buildings. In the room without water spray and office, the PHRR is 6MW. In order to ensure the fire source is representative, the fire power set between 1.5MW ~6MW.

$$Q_f = 1.5\text{~}6\text{MW} \tag{1}$$

The scope of the fire power of the indentation size model experiment table is:

$$Q_m = 265.2\text{kW}\text{~}1.06\text{MW} \tag{2}$$

Finally, we determine the fire power of 350 kW.

We change the number of the fire overhang which added on Smooth frame to control it extended length of fire overhang above the window. The thermocouples are set in rank on the window on the facade of burning room every 15cm from the top edge of window to lower and each thermocouple is set every 15 cm in each rank. At the floor above burning floor, the thermocouples are set in rank every 15cm from the lower edge of window to top and each thermocouple is set every 15cm in each rank. Between the top edge of window on second floor and the lower edge of window on third floor, the thermocouples is set in rank every 15cm and each thermocouple is set every 15cm in each rank (as shown in figure 2).

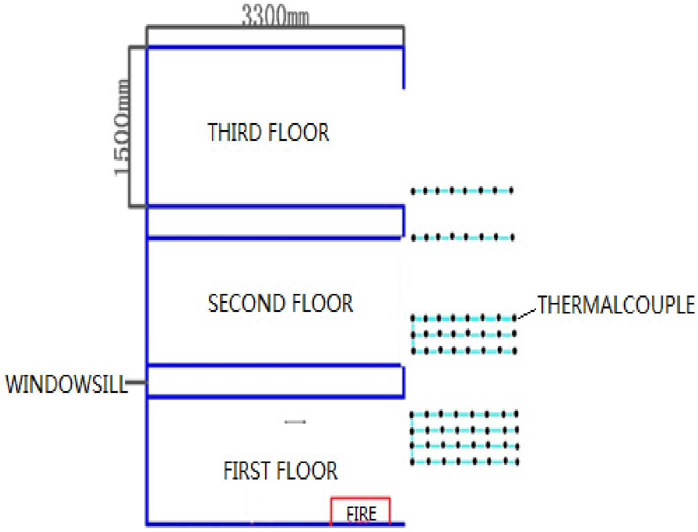


Figure 2: Distribution of thermocouples

*2.3 Experimental operating conditions*

On the condition without outdoor wind, we selected 5different extended length of fire overhangs, 0 m, 0.2 m, 0.4 m, 0.6 m, 0.8 m. The height of windowsill wall is 0.5 m and the width of window is 1.2 m.

*2.4 The selection of critical temperature of dangerous*

According to the research from Zhang et al. from the university of science and technology in china, the exposed surface minimum temperature is 70 ℃ when the 6 mm common glass was broken under the high temperature. We select 70 ℃ as critical temperature of dangerous since this paper analyses the fireproof performance of fire overhangs on the most unfavorable conditions.

*2.5 Experimental results and analysis*

The following two tables are horizontal temperature distribution of five different extended length of fire overhangs at distance 1.8 m from the ground (lower edge of window above burning floor), and 1.95 m, and the abscissa is distance that from thermocouple measuring point to the wall. It can be seen from the chart that fire plume overflow from the window and spreads upward along the outer wall surface when the top of the window of burning floor doesn't add fire overhangs and the temperature of two measuring point at the top of the window of burning floor is 135 ℃, 116.6 ℃, and the peak value that appears at distance of 0.15 m and 0.03 m from the wall which is greater than the critical temperature of 70 ℃. It is shown in the chart that with the extended length of fire overhangs increasing, the decrease of the temperature is more obvious when add fire overhangs. When the length of fire canopy extends to 0.2m, the temperature of the window above burning floor slightly decrease. The two measured points that set above the lower edge reduce to 80℃, 81.6℃ which are greater than critical dangerous temperature. With the distance from the wall increasing, the temperature increase. When the length of fire overhangs extends to 0.4m, the two measuring points are 88.5℃, 90.4℃ and the temperature of fire plume increase with the distance from the wall at the place 0.15 m from wall which poses threat to the floor above burning floor, as the two measuring points reduce to 62.5 ℃, 53.5 ℃ and which are less than the critical dangerous temperature of 70 ℃. Within a distance of 0.45 m from the wall, the temperature reduced to 70 ℃ which could better barrier the spread of the fire plume when the length of fire overhangs extends to 0.6 m. By the followed three charts, when the balcony elongation of 0.6 m and the distance from the wall within 0.75 m, the curve almost identical. But the temperature has a larger ascension at the place 0.9 m from the wall and it may pose threat to adjacent buildings when fire come into the room through the adjacent building's window.

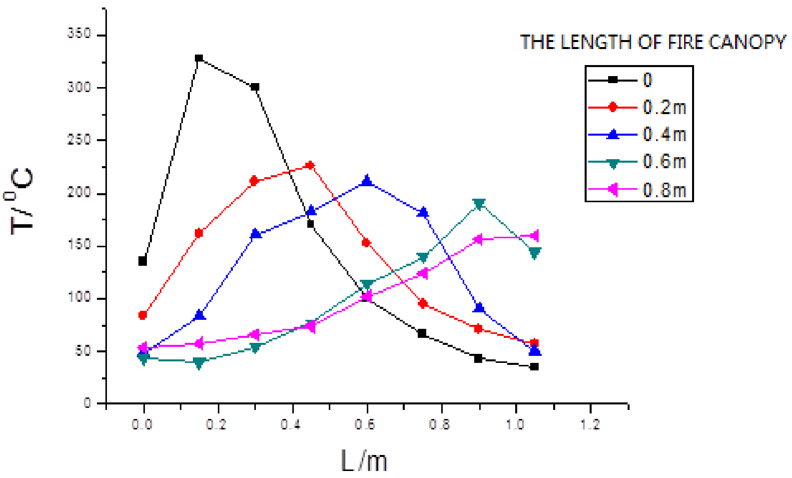


Figure 3: 1.8m from the ground

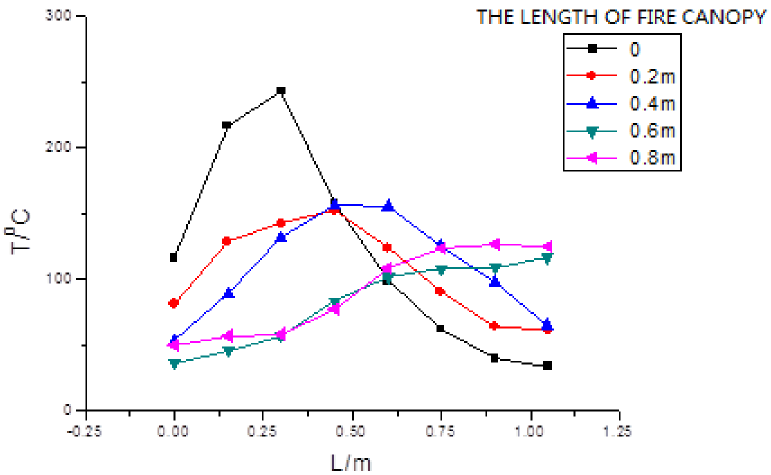


Figure 4: 1.95m from the ground

## 3. The numerical simulation

### *3.1 The establishment of the fire model*

The fire model is completely established according to the conditions of 1/2 size shrinkage experiment which including the model size (4720 mm * 3780 mm * 3780 mm), the size of the fire power (350 kw), thermocouple and fire overhangs as the following figure 5.

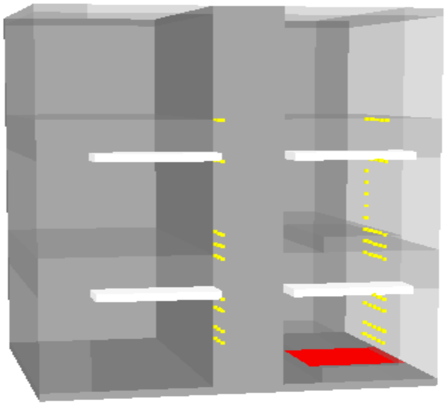

Figure 5: Fire numerical model

### *3.2 Analysis of simulation results under no wind*

As shown in figure 6 to figure 9, the correlation curve of experimental result and the FDS simulation results is plotted when the extended length of fire overhangs are 0.2 m, 0.4 m, 0.6 m, 0.8 m. It can be seen from the curve, the two curves fit well. FDS simulation results are similar to experimental results which could accuracy the results, and which proved the correctness of the numerical model. It can be seen from the graph, when fire overhangs elongation of 0.6 m, the trends of temperature variation of different vertical height and the corresponding horizontal extension direction are similar along the lower edge of the window above the burning floor. When fire overhangs elongation to 0.8 m, the temperature distribution is similar to which to 0.6 m.

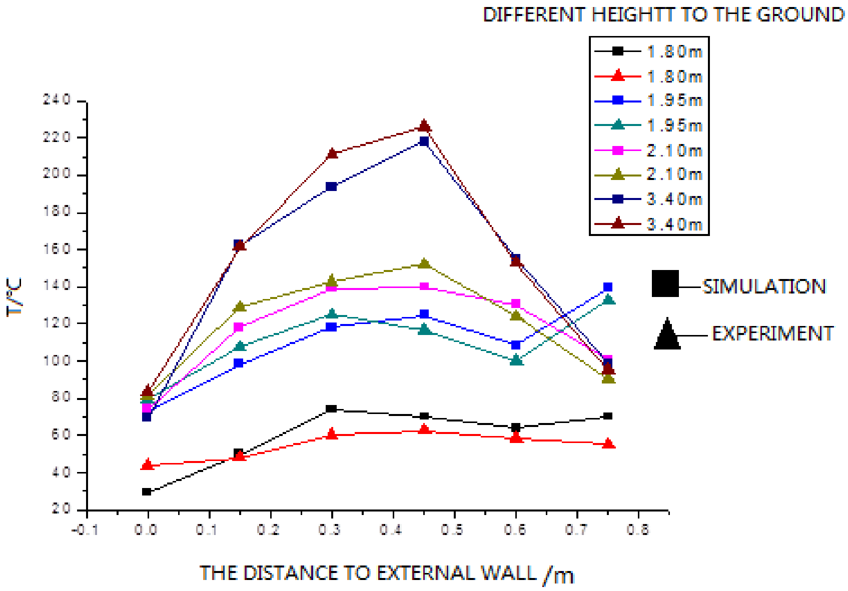


Figure 6: Extended length of fire overhangs is 0.2m

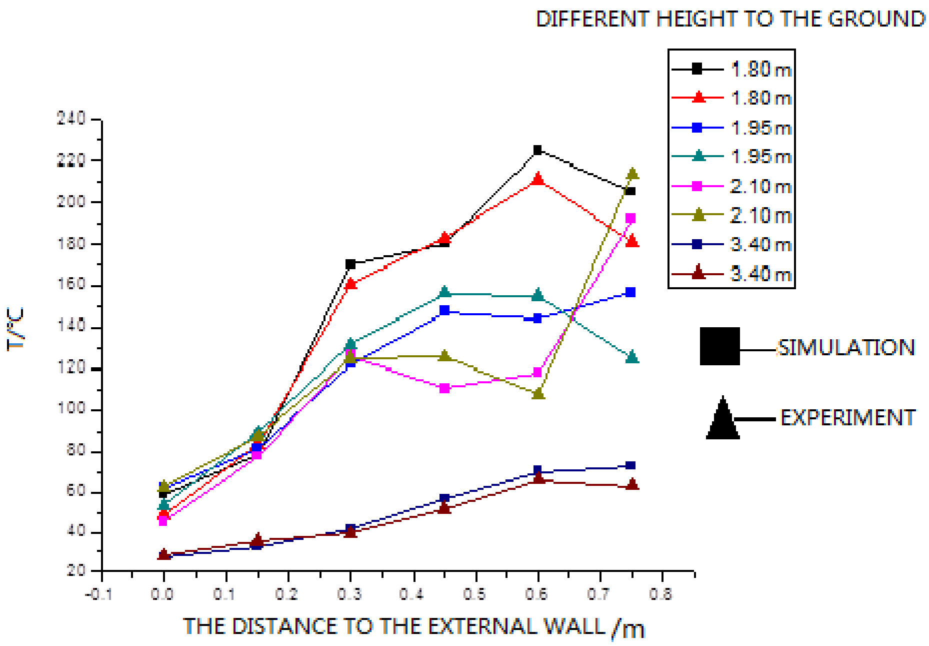


Figure 7: Extended length of fire overhangs is 0.4m

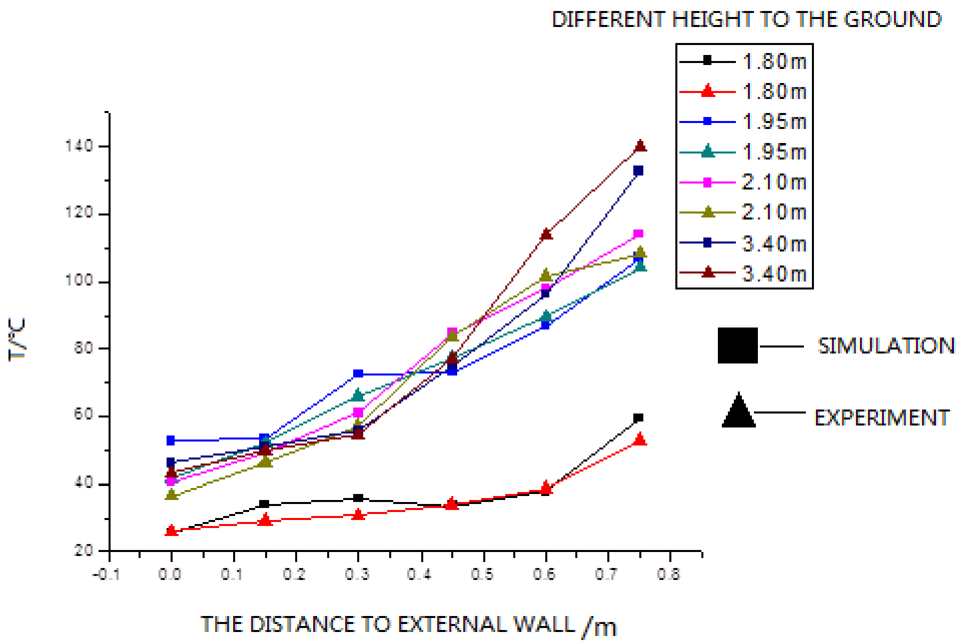


Figure 8: Extended length of fire overhangs is 0.6m

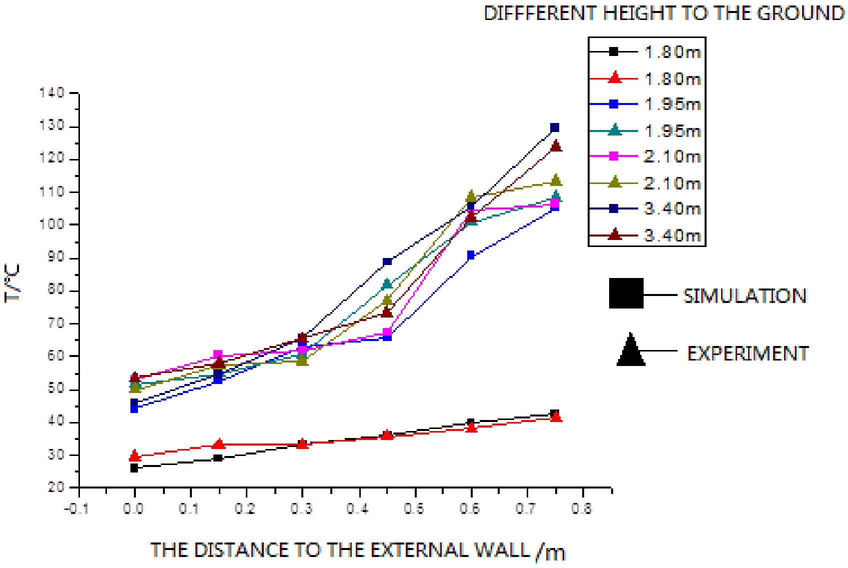


Figure 9: Extended length of fire overhangs is 0.8m

*3.3 Analysis of simulation results under the wind outside*

It is shown by the above experiment and simulation, when the extended length of fire overhangs is 0.6 m, the effect of barring fire plume's spread from the opening is well and the results of experiment and simulation are similar. Based on the fire simulation model, we could research the barrier effect of fire overhangs under different wind speed by simulating right crosswind which speed are 2 m/s、3 m/s、4 m/s、5 m/s and 6 m/s.

The figure 10 shows that the spreading direction of fire plume from the window trends to level continuously under the effect of the outdoor wind because of the increase of the wind speed. The fire plumes ramp above when the wind speed less than 4m/s. When the wind speed is greater than 4 m/s, the fire plume spread along the level. When the wind speed is 3 m/s, the temperature of vertical spread fire plume is greatest and the fire overhang cannot effectively barrier the vertical spread of fire when which is 0.6 m in length, of which the temperature of the window both above 70 ℃ at distance 1.8 m、1.95 m and 2.10 m from the ground which could break the glass and cause the fire spread into the room.

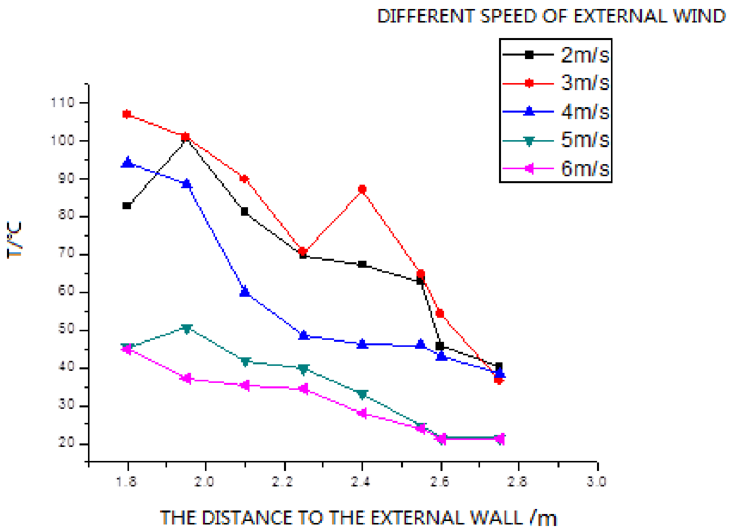


Figure 10: The fire overhangs' effect of barring fire plume spread at different wind speed

Due to the fire overhangs cannot effectively barrier the vertical spread of fire plume under outdoor wind, so we consider to change the height of the windowsill wall to assist fire overhang's barrier effect. Selected windowsill wall height is 0.3 m, 0.4 m, 0.5 m, 0.6 m and 0.7 m.

The figure 11 shows that when the outdoor wind speed is 3 m/s, height of windowsill wall is 0.4 m and the fire overhangs extend to 0.6m, the temperature is below 70 ℃ at different height above the lower edge of the window above the burning floor and which effectively block the vertical spread of fire. When the height of windowsill wall is greater than 0.4m, the temperature of the window above the burning floor increase since the distance between fire source and the fire overhangs increase, which make the unexploded material fully burn under fire overhangs and increase the included angle between overflowing fire plume and façade, the fire can spread upward from the outward of fire overhangs.

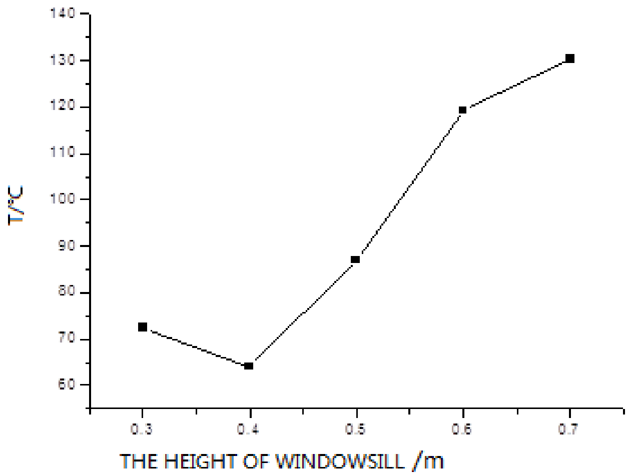


Figure 11: The effect of height of windowsill wall to fire overhangs' effect of barring fire

## 4. Conclusion

By 1/2 scale building external facade flame experiment and FDS fire simulated experiment, this page research the block effect of fire overhangs' to fire plume spread from building facade under the condition with outdoor wind and without outdoor wind. We got the following conclusion in order to provide some reference opinions of improving the barrier performance of barrier facilities.

(1) Under ideal state which without wind, the temperature above the burning floor decrease with the extended length of fire overhangs increase and the block effect is obvious gradually. When the extended length of fire overhangs is 0.6 m, the block effect to vertical spread of fire plume is best. When fire overhangs elongation to 0.8 m, the block effect of vertical spread of overflow fire does not increase and it cause the overflow fire plume spread to the top of window and neighboring building along the cornice.

(2) By FDS simulation under the same condition of 1/2 scale building external facade flame experiment and comparative analysis, the results from the simulation and the experiment are similar and it proves the credibility of the results and the accuracy of FDS simulation software to build models. So it can lay a certain foundation of research of building facade fire with the help of simulation software in further research.

(3) Under the condition of external wind, when the wind speed is 3 m/s and the extended length of fire overhangs is 0.6 m, the fire overhangs cannot effectively block the overflow fire plume spread vertically and the temperature of the window above the burning floor can reach the greatest value. When windowsill wall which is 0.4 m in height is added, the fire overhangs which extended length is 0.6 m still can effectively block the overflow fire plume spread vertically.

Under the condition of outdoor wind, when the wind speed is 6 m/s, the fire plume from building facade opening will spread along the level, and it poses less threat to the floor above burning floor but the neighbor window on the level. So, for building facade fire, we not only need consider the barrier facilities in vertical, but also need consider the barrier facilities in the level to ensure the security of building facade.

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